GPM Science Status in U.S.

Arthur Y. Hou

NASA Goddard Space Flight Center

6th GPM International Planning Workshop, November 6-8, 2006
Annapolis, Maryland, USA

GPM

An international satellite mission to unify and advance global precipitation measurements

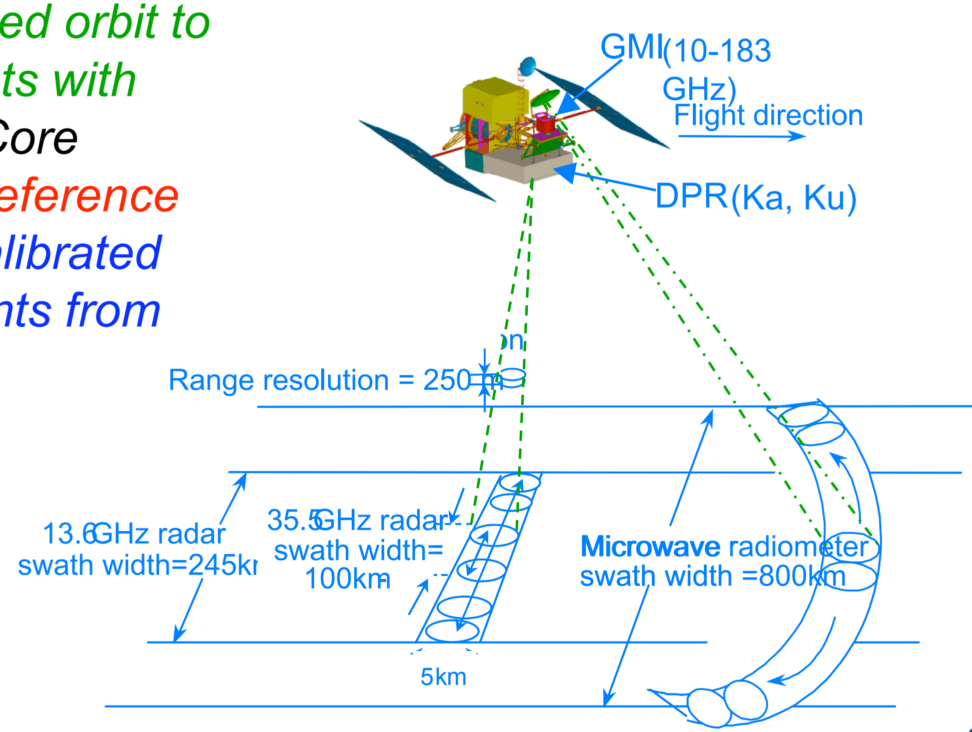
- *Improve understanding of precipitation physics*
- *Unify a constellation of dedicated & operational passive microwave sensors to provide accurate & timely global precipitation measurements for research & applications*

A research satellite mission dedicated to improving global precipitation measurements

Unique Capabilities

- *Core Spacecraft carries a dual-frequency radar & a multi-frequency radiometer with HF capabilities to provide measurements of 3-D precipitation structures and microphysical properties to serve as a precipitation physics observatory for improved understanding of precipitation processes and retrieval algorithms.*

- *Core Spacecraft in a 65^o inclined orbit to provide coincident measurements with partner satellites, enabling the Core radar/radiometer to serve as a reference standard to provide uniformly calibrated global precipitation measurements from constellation radiometers:*
  - *uniform calibration of brightness temperatures*
  - *common cloud/hydrometeor database for precipitation retrievals*



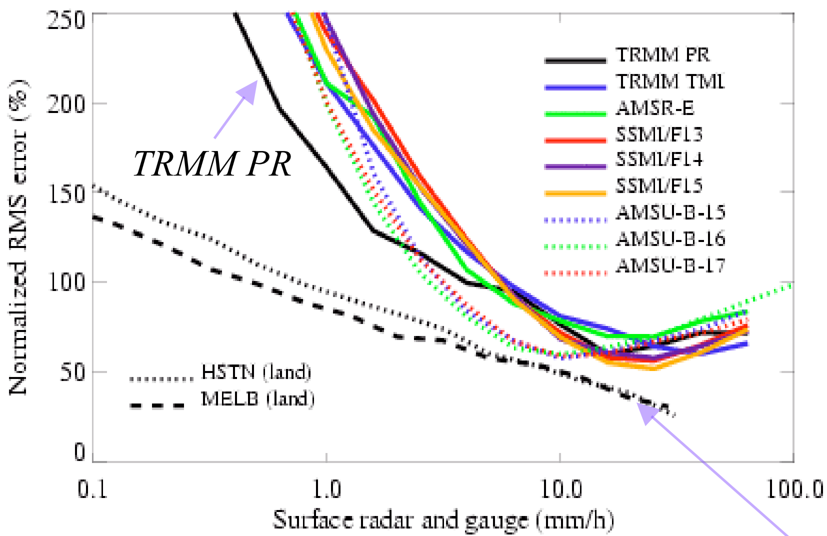
GPM Science Update

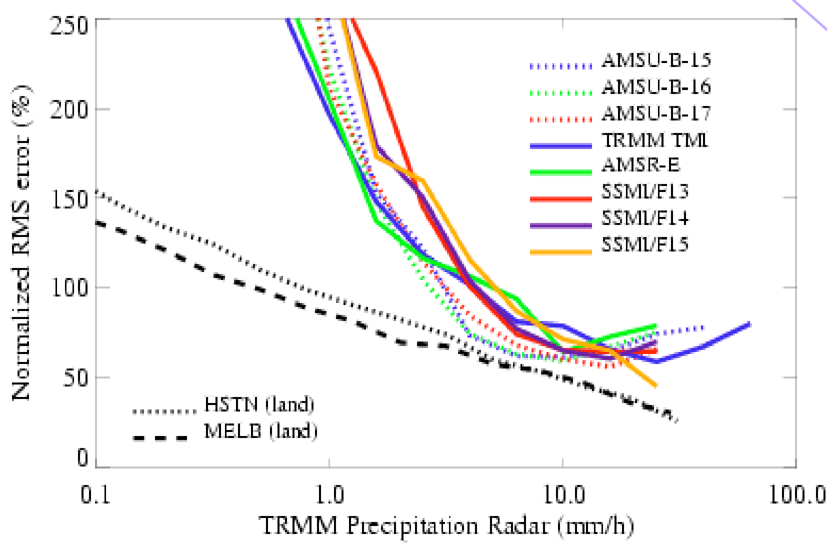
- ***GPM constellation reconfiguration building on latest advances in AMSU-B sounder algorithms & GMI high-frequency capabilities:***
  - *Scientific basis for the baseline GPM constellation reconfiguration*
  - *Enhancement of GPM measurement & sampling capabilities*
- ***Development of satellite simulators, retrieval algorithms, and model applications through "ground validation"***
  - *GPM GV advisory panel white papers released (Oct. 2005 & Sept. 2006)*
  - *GPM participation in Canadian CloudSat/CALIPSO Validation Program (C3VP) in winter 2006-2007*
  - *Initial discussion of U.S.-Finland GV collaboration*
- ***New NASA Precipitation Measurement Missions (PMM) Science Team***
  - *Focused GPM research in the coming years include: inter-satellite calibration,*
    light rain & falling snow retrievals (especially over land), and
    downscaling of satellite precipitation data for hydrological applications

Surface Rain Retrievals from Microwave Sensors Over Land

0.25° instantaneous retrievals within hourly windows (Jan-Dec 2005)

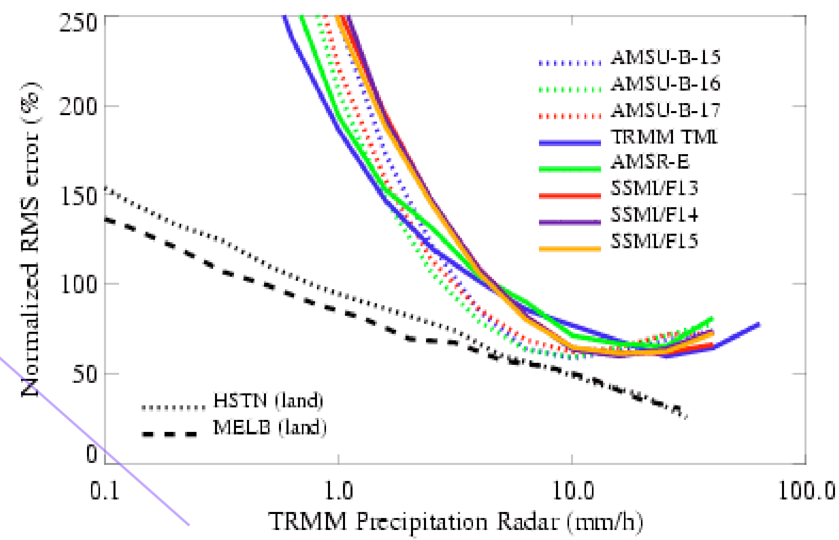
Over U.S. (South of 35N)





Sounder retrievals with HF water vapor channels are closer to PR than C-S imagers without HF between 1-10 mm/h

Over Tropical Land (35N-35S)



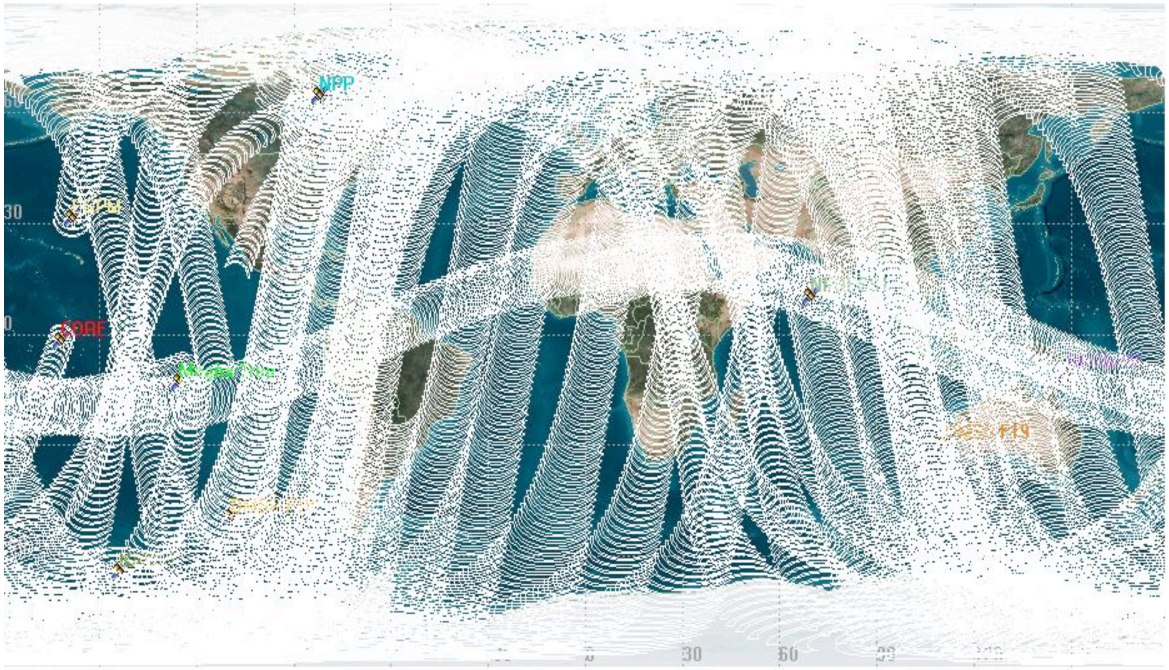
RMS errors due to temporal mismatches within 1h observation window for perfect retrievals

Lin & Hou (2006)

GPM Constellation Reconfiguration

GPM originally conceived as a satellite mission that provides
precipitation measurements around the globe approximately every 3 hours
by conically-scanning radiometers

3 Hour Coverage by GPM Core and 7 Constellation Radiometers



comprising dedicated and operational satellites:

GPM Core, F18, F19, GCOM-W, Megha-Tropiques, NASA-1, Partner-1, Partner-2

Average Revisit Times by Passive Microwave Sensors in GPM Era

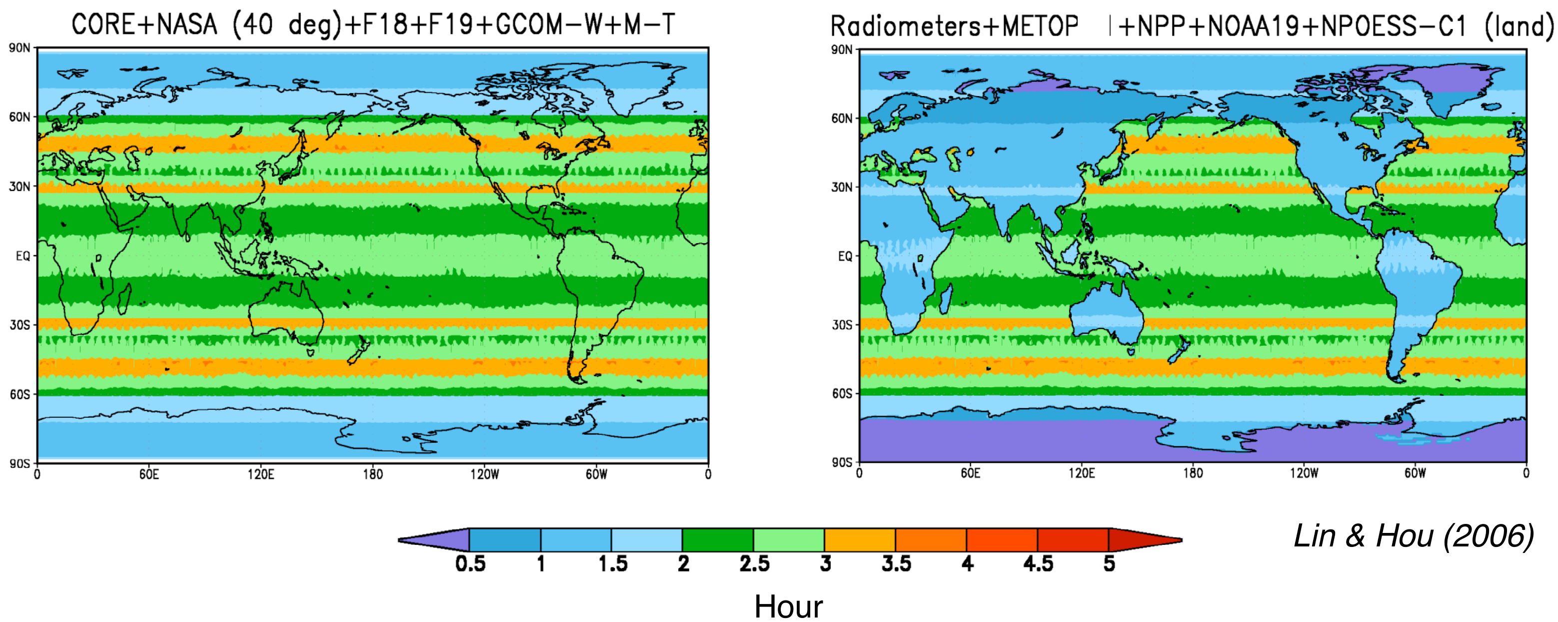
Reconfiguration to include crossing-track PMW sounders over land

6 Conically-Scanning Imagers

(≤ 3h over 86% of globe)

6 C-S Imagers Plus 4 Cross-track Sounders Over land

(≤ 3h over 92% of globe)



Lin & Hou (2006)

GPM Core, NASA-1(40^{o}), F18, F19 GCOM-W, Megha-Tropiques

With addition of MetOp-B, NPP, NOAA-19, & NPOESS-C1 over land

NPP & NPOESS-C1 will each contribute an ATMS to GPM

Passive Microwave Sensor (PMW) Characteristics in GPM Era

Constellation microwave sensor channel coverage

V – Vertical Polarization **H – Horizontal Polarization**

Channel	6 GHz	10 GHz	19 GHz	23 GHz	31/36 GHz	50-60 GHz	89/91 GHz	150/166 GHz	183/190 GHz
AMSR-E	6.925 V/H	10.65 V/H	18.7 V/H	23.8 V/H	36.5 V/H		89.0 V/H		
GMI		10.65 V/H	18.70 V/H	23.80 V	36.50 V/H		89.0 V/H	165.5 V/H	183.31 V
MADRAS			18.7 V/H	23.8 V	36.5 V/H		89.0 V/H	157 V/H	
SSMIS			19.35 V/H	22.235 V	37.0 V/H	50.3-63.28 V/H	91.65 V/H	150 H	183.31H
MHS							89 V	157 V	183.311 H 190.311 V
ATMS				23.8	31.4	50.3-57.29	87-91	164-167	183.31

Mean Spatial Resolution (km)

Channel	6 GHz	10 GHz	19 GHz	23 GHz	31/36 GHz	50-60 GHz	89/91 GHz	150/166 GHz	183 GHz
AMSR-E	56	38	21	24	12		5		
GMI		26	15	12	11		6	6	6
MADRAS			40	40	40		10	6	
SSMIS			59	59	36	22	14	14	14
MHS							17	17	17
ATMS				74	74	32	16	16	16

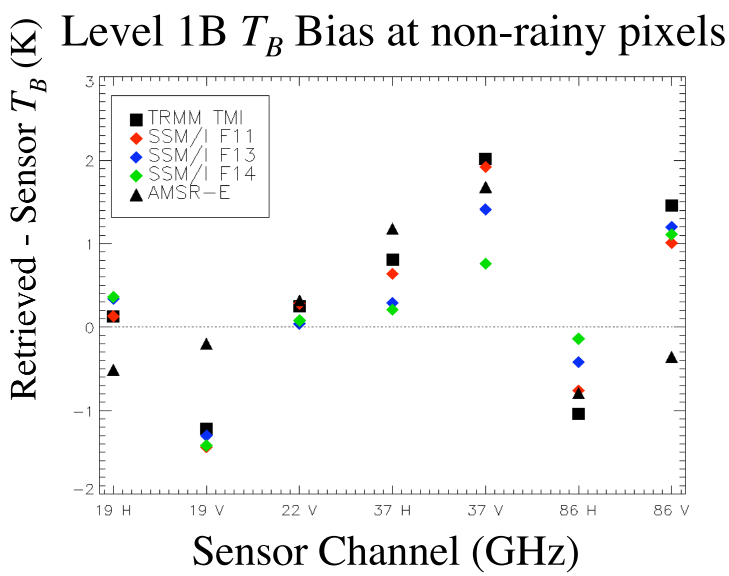
Different center frequencies, viewing geometry, and spatial resolution must be reconciled

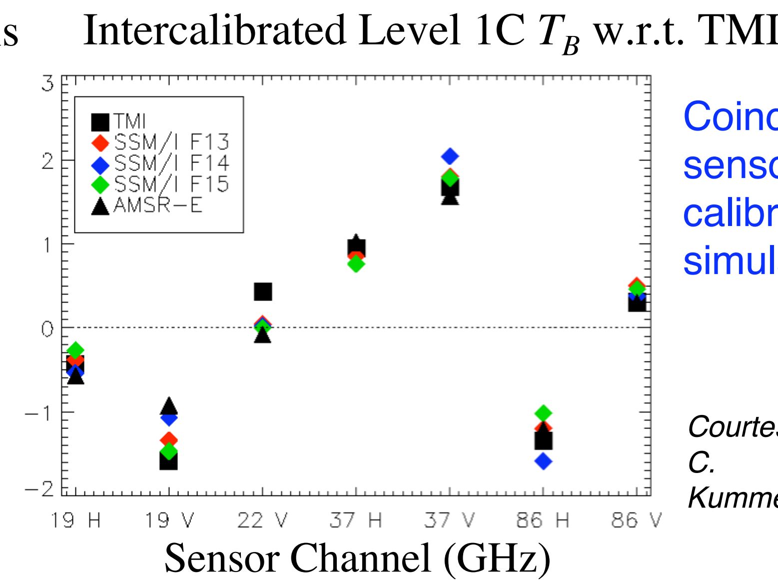
GPM will provide a consistent framework to unify a heterogeneous constellation of PMW sensors (both C-S imagers and X-T sounders)

Making combined use of DPR & GMI on GPM Core Spacecraft to provide

- a uniform calibration of brightness temperature measurements and

- a common cloud/hydrometeor database for precipitation retrievals





Coincident sensor T_B calibrated to simulated TMI T_B

Courtesy C. Kummerow

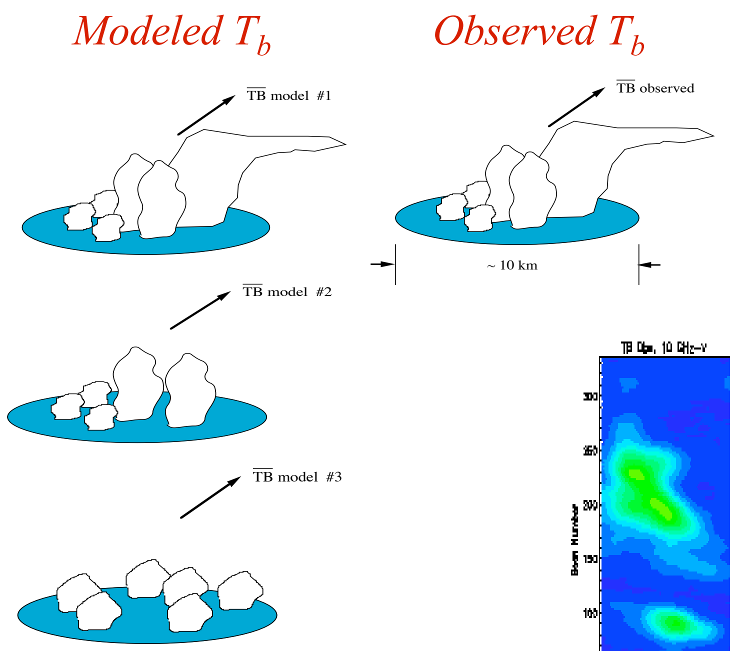
Using DPR+GMI on GPM Core to calibrate coincident T_B's rainy and non-rainy pixels

L1C homogenizes L1B for precipitation retrieval without replacing official L1B products

An open community effort: http://mrain.atmos.colostate.edu/LEVEL1C/

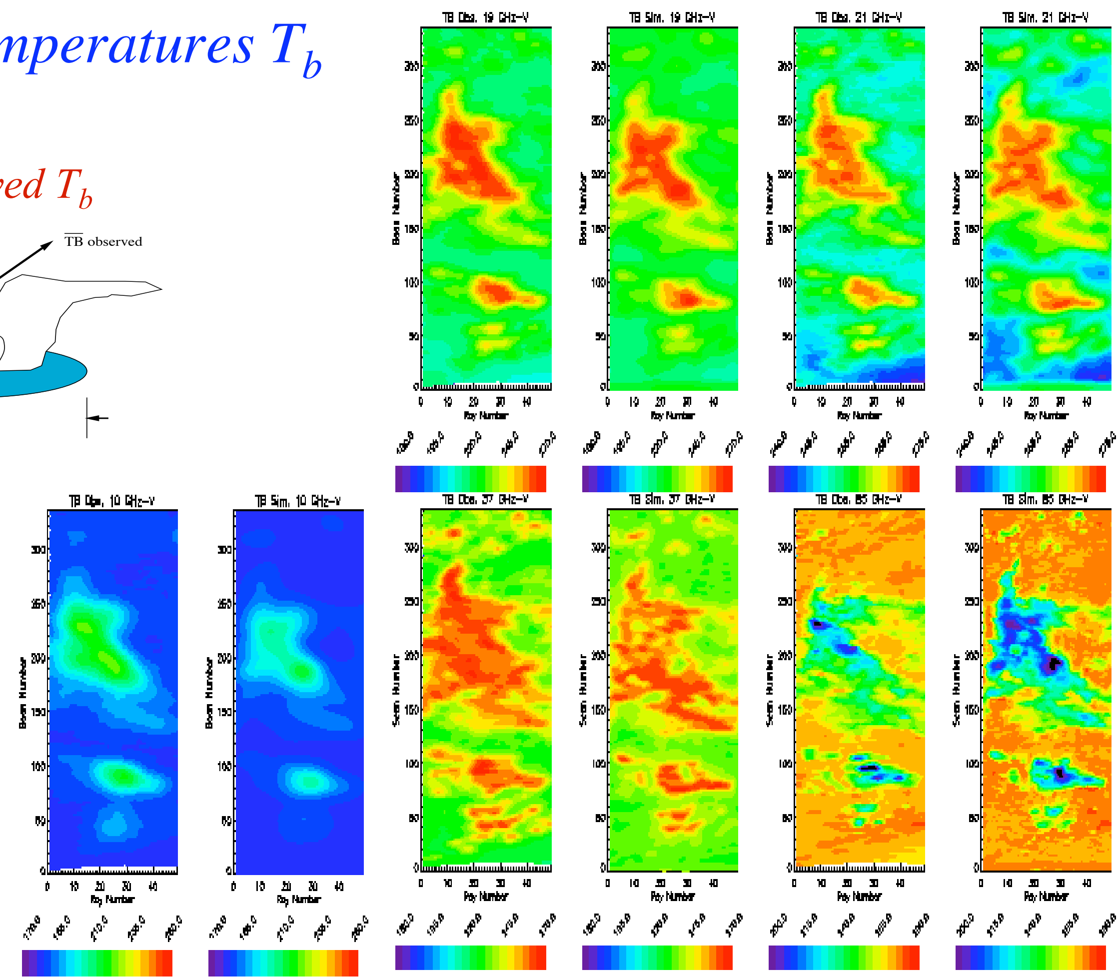
GPM will provide a *common cloud database* for physical retrievals of precipitation information from PMW sensors

Matching simulated and observed microwave brightness temperatures T_b

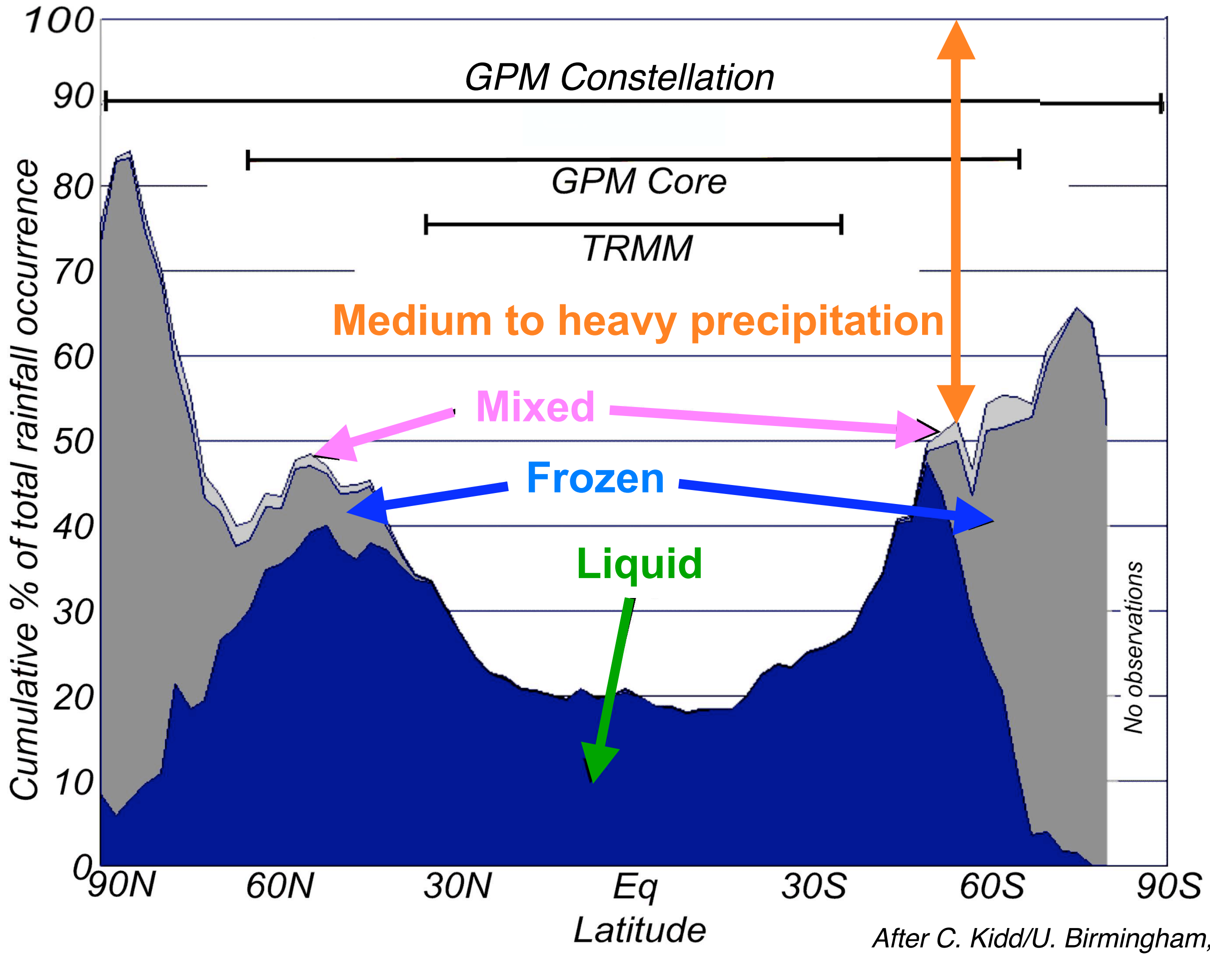


Courtesy W. Olson (NASA/GSFC)

Simulated vs. observed TMI T_b



New Challenges: Measuring Light Rain & Falling Snow



After C. Kidd/U. Birmingham, UK

Both DPR and GMI will have greater sensitivities relative to TRMM for light rain and solid precipitation detection

GPM "Ground Validation"

"Ground validation" activities during GPM pre-launch provide the means for improving satellite simulators, retrieval algorithms, & model applications

GPM GV Advisory Panel White Paper #1 recommends 3 categories of validation activities

- ***Direct statistical validation:***

  - Leveraging off national networks to identify and resolve significant discrepancies between satellite and ground-based precpitation estimates

- ***Precipitation process validation:***

  - Cloud system and microphysical studies geared toward algorithm testing and refinement

- ***Integrated science validation:***

  - Integration of satellite precipitation products into weather, land surface, and hydrological prediction models to evaluate the strengths and limitations of products

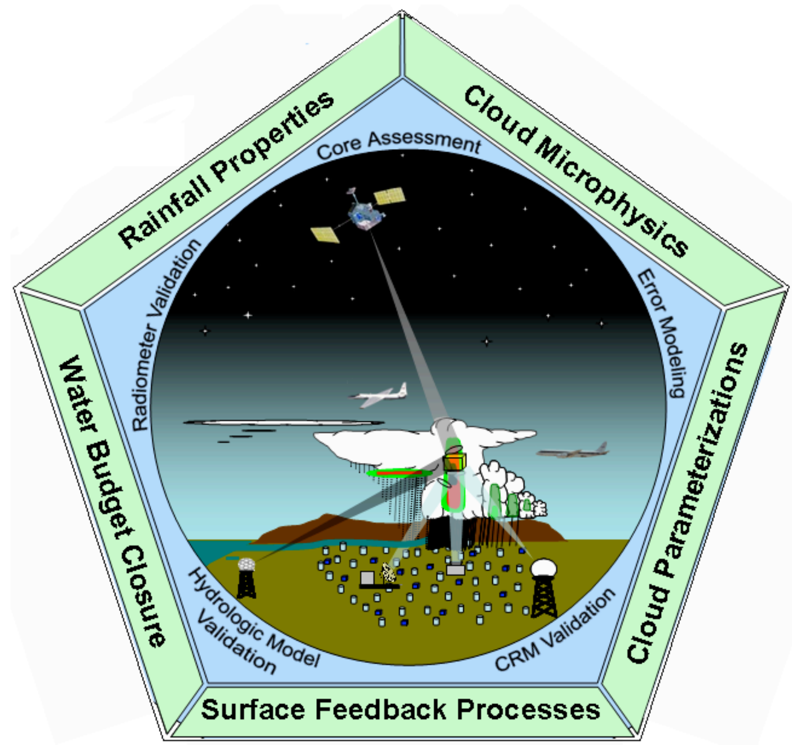
International GPM GV collaboration is key to global product validation

GPM Ground Validation Objectives

GPM GV Advisory Panel White Paper #2 recommends:

5 cross-cutting GV science objectives for direct validation, physical process, & integrated science studies:

1. Core satellite error characterization
2. Constellation satellites validation
3. Improved physical models of snow, cloud water, and mixed phase
4. Better cloud-resolving models to bridge observations & algorithms
5. Developing coupled CRM-land surface models for basin-scale water budget studies



Next steps towards GPM GV Implementation:

1. Direct validation using national networks: Developing prototype infrastructure and algorithms for automated NEXRAD–PR (later DPR) comparisons for 20 radars in southeast U.S.

2. Process Studies: Prototype winter storm measurements for snowfall retrieval algorithm development with Canadian ClodSat/CALIPSO Validation Program (C3VP) in winter 2006-07.

3. Integrated coupled modeling: Developing fully-coupled physically-based modeling system including land-surface, atmosphere, precipitation and radiative transfer simulations/interactions model.

4. Collaboration with *EarthCARE* satellite simulation activity: shared expertise, similar objectives, separate simulation software.

5. Winter precipitation, snow pack and land-surface observations: Collaboration with FMI under discussion (next planning meeting in Helsinki in Feb. 2007).

6. Developing links to NOAA MPE and IPWG products for national direct rain rate validation

7. Developing links to future campaign opportunities of interest to GPM (AMMA, SHARE, COPS, TPARC etc.).

GPM Participation in the Canadian CloudSat/Calipso Validation Program (C3VP):Winter 2006-2007

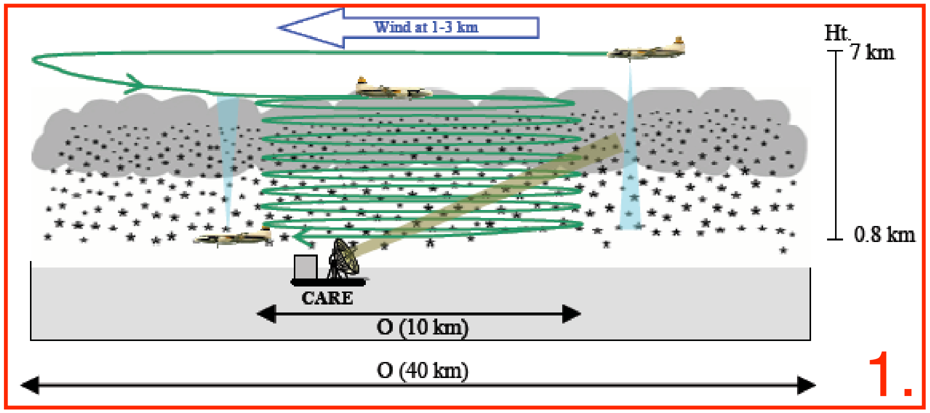
- ***UMass Advanced Multi-Frequency Radar (AMFR) – January 2007***

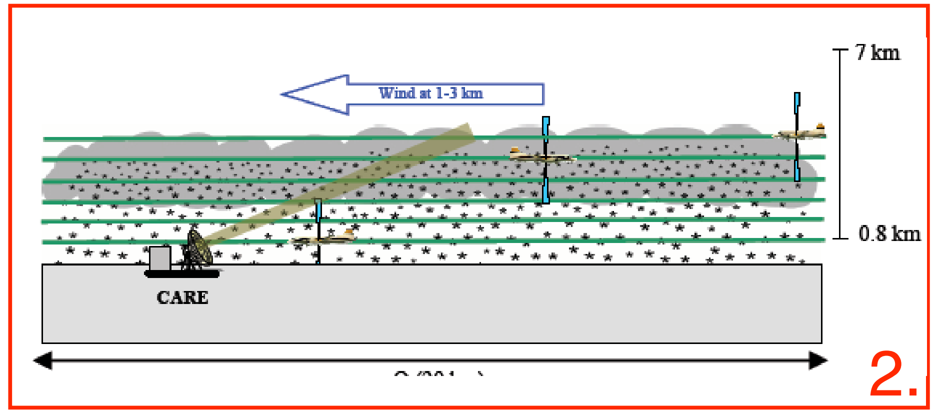
1. Ku/Ka/W bands
2. Matched 0.7^{o} beams
3. Antenna scans at 1^{o} sec^{-1} from 0° to 90° in elevation and ±135° in azimuth

- ***GSFC Parsivels – November 2006 through February 2007***
  – Measures hydrometeor numbers, sizes (maximum width), type, and fall speeds

- ***2D Video Disdrometers (Colorado State U.) - Jan. 2007***
  – Measures hydrometeor concentrations, sizes (equivalent diameter), shapes, and fall speeds

GPM-Proposed Flight Patterns During C3VP

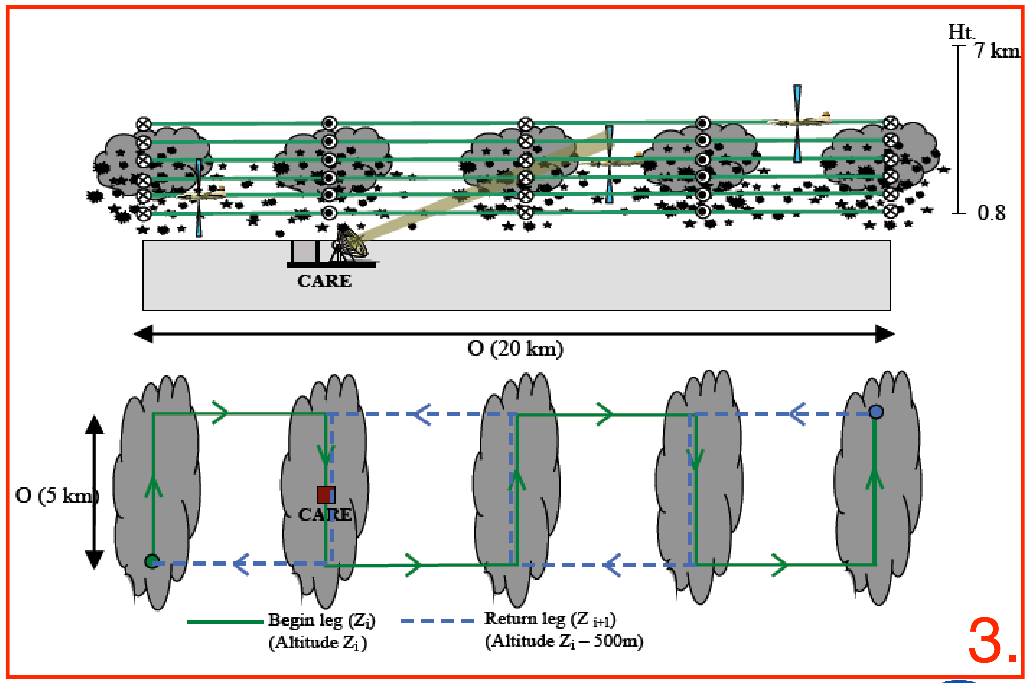




1. Broad precipitation system: Spiral pattern. Designed to measure vertical structure of microphysics over surface CARE instrumentation and within sampling volume of AMFR.

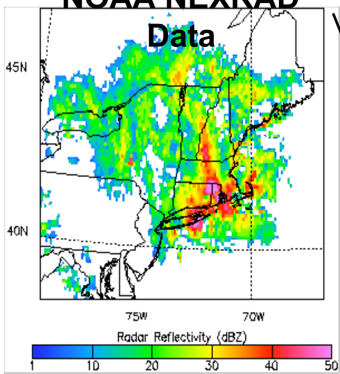
2. Lake effect band: Stacked parallel pattern. Designed to sample vertical structure of a snow band.

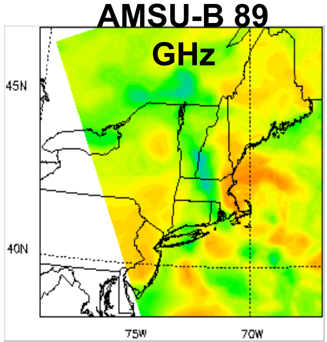
3. Lake effect band: Stacked "square waves". Designed to sample both vertical structure and horizontal heterogeneity between bands.

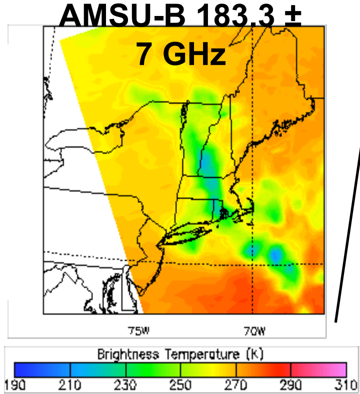


Courtesy Walt Petersen

Realistic microphysics for improving falling snow retrievals

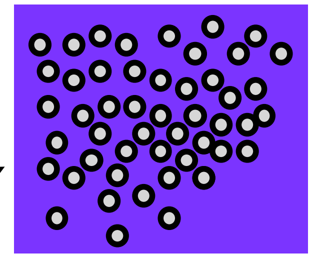




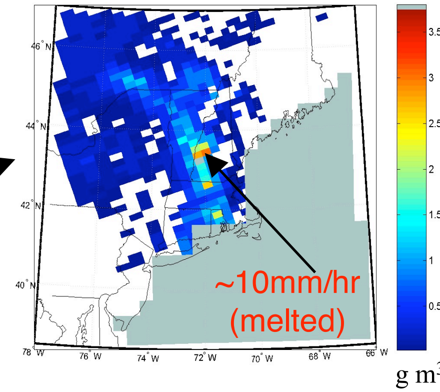


March 2001
AMSU-B T_B
Used to
Estimate
Snow rate

Snow as spheres

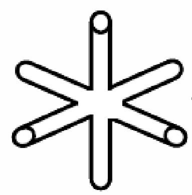


Grenfell & Warren,
JGR 1999
Preserves volume and
surface area of
non-spherical snow shapes

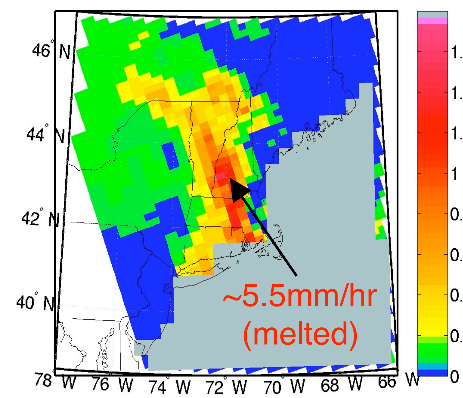


C3VP will
provide data on
snow sizes &
shapes, plus
radiative
properties

Non-spherical
Snow



Collection of cylinders
With aspect ratios from
Auer and Veal, JAS 1970



Courtesy G. Skofronick-Jackson and M.-J. Kim

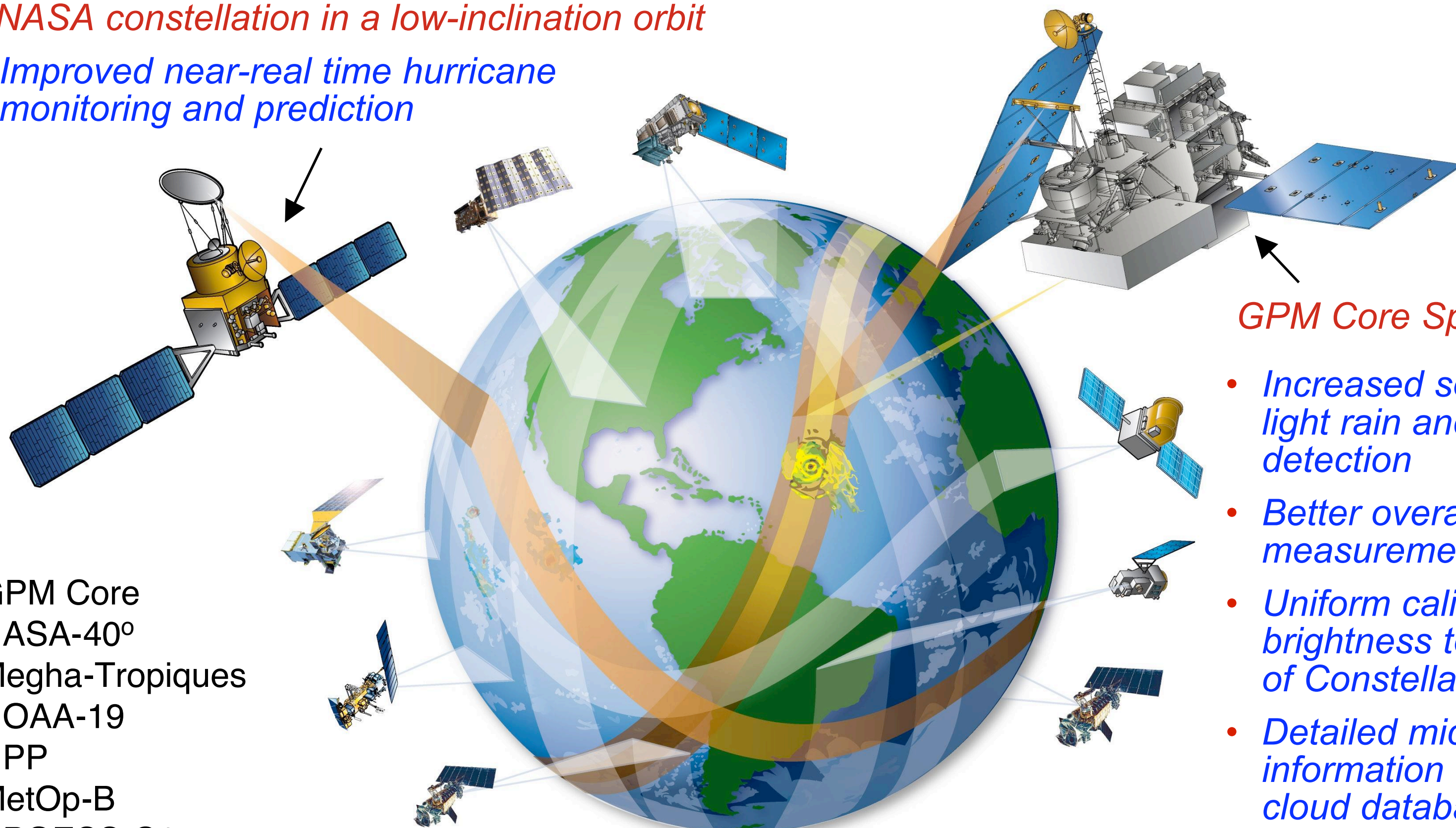
GPM Science

Unify and advance global precipitation measurements through

- *advanced microwave sensors & algorithms (DPR & GMI)*
- *a consistent framework for inter-satellite calibration*
- *international science collaboration in algorithm development, ground validation, and improved use of precipitation data in research & applications*

NASA constellation in a low-inclination orbit

- *Improved near-real time hurricane monitoring and prediction*



GPM Core
NASA-40º
Megha-Tropiques
NOAA-19
NPP
MetOp-B
NPOESS-C1
GCOM-W

GPM Core Spacecraft

- *Increased sensitivity for light rain and snow detection*
- *Better overall measurement accuracy*
- *Uniform calibration of brightness temperatures of Constellation sensors*
- *Detailed microphysical information and a common cloud database for rain & snow retrievals from Core & Constellation sensors*